Q 63: Quantengase (Wechselwirkungseffekte II / Spinorgase)

Zeit: Freitag 14:00–16:00 Raum: 3G/H

Q 63.1 Fr 14:00 3G/H

Metastable neon atoms in optical dipole traps: collisional properties of different internal states — •W.J. van Drunen[1], E.-M. Kriener[1], J. Schütz[1], N. Herschbach[1], W. Ertmer[2], and G. Birkl[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

After performing a detailed analysis of the collisional properties of metastable neon atoms ($^3P_2$, m=+2) in a magnetic trap [1], we implemented an optical trap for metastable neon for further investigations. This enables us to explore possibilities to manipulate interactions and extend our studies of interactions to states, which are not magnetically trappable.

As a result, we could demonstrate the first trapping of metastable neon ($^3P_0$) atoms. Measurements of the number decay of trapped atoms allows us to determine the rate coefficient for two-body loss of neon in the $^3P_0$ metastable state for both bosonic isotopes ^{20}Ne and ^{22}Ne. In addition to the requirements of our previous quantitative studies [1], a careful characterization of the optical trap is required as well.

[1] P. Spoden et al., Phys. Rev. Lett. **94**, 223201 (2005)

Q 63.2 Fr 14:15 3G/H

Cavity QED with a Bose-Einstein Condensate — •Ferdinand Brennecke, Tobias Donner, Stephan Ritter, Thomas Bourdel, Michael Köhl, Christine Guerlin, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

Cavity quantum electrodynamics (cavity QED) studies the coherent interaction of light and matter inside a high-finesse resonator. One of the main challenges in present experiments within the optical regime of cavity QED is to achieve a deterministic coupling strength between atoms and light, which in particular requires high control over the atomic external degrees of freedom. Using a Bose-Einstein condensate (BEC), we enter a new regime of cavity QED where all atoms couple identically to the cavity field. Here we present a measurement of the energy spectrum of this strongly coupled system in the low excitation limit. Due to a collective coupling of several GHz we observe a significant coupling of the BEC to higher-order transverse cavity modes. The strong coupling even of a single atom to the cavity mode offers the possibility to detect and manipulate a minority component of atoms in a different hyperfine state embedded within a BEC. Besides its relevance to the field of quantum information processing, the presented system offers a variety of interesting phenomena expected in the many-body physics of quantum gases within a quantum optical lattice. In contrast to the case of optical lattice potentials provided by strong laser fields, here the light field itself becomes a dynamical quantity depending on the atomic distribution, which leads to substantial cavity-mediated long-range interactions between the atoms.

Q 63.3 Fr 14:30 3G/H

Dipole Oscillations of a Bose-Einstein Condensate in Presence of Defects and Disorder — •Mathias Albert, Nicolas Pavloff, Patricio Leboeuf, and Tobias Paul — Laboratoire de Physique Théorique et Modèles Statistiques, Universite Paris Sud

We study the influence of a weak defect or disorder potential on the dipole modes of a weakly interacting Bose Einstein condensate, confined in a harmonic cigar-shaped trap with a tight transverse confinement but a shallow axial trapping frequency in presence of an external defect or disorder potential. We show that for small-amplitude dipole oscillations the BEC-flow is superfluid and the dipole oscillations are almost undamped, but the external defect potential induces a small shift of the excitation frequency. We compute this frequency shifts by use of a perturbative approach, both in the low-density regime and in the Thomas-Fermi large-density regime and apply this approach -as a first test- to a single Gaussian-shaped barrier potential. Then, we consider the experimental relevant case of an optical speckle-potential where we find uncorrelated frequency shifts of the dipole mode with respect to the pure harmonic case. This behavior is confirmed by numerically solving the Gross-Pitaevskii equation. Finally, we derive a relation between the disorder correlation-function and the ensemble-averaged fluctuations of the frequency shift. This opens the perspective for experiments to obtain from the dipole-frequency fluctuations characteristic parameters of the disorder potential (e.g. correlation lengths).

Q 63.4 Fr 14:45 3G/H

Far-from-equilibrium dynamics of ultracold Bose gases — •Philipp Struck and Thomas Gasenzer — Institute for Theoretical Physics, University of Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of a Bose-Einstein condensate trapped in a one-dimensional optical lattice is investigated in the framework of the Bose-Hubbard model. Of special interest is the far-from equilibrium evolution of a strongly interacting gas. Using functional integral techniques, the dynamic equations are derived from the two-particle-irreducible effective action expanded in inverse powers of the field components. This approach reaches far beyond the Hartree-Bogoliubov mean-field theory and Quantum Boltzmann approaches. Within this framework we investigate various configurations of one-dimensional lattices of particular interest for present experiments. This includes dipole oscillations of a condensate damped by the thermal cloud and squeezing of particle number fluctuations below the classical limit.

Q 63.5 Fr 15:00 3G/H

Non-Abelian dynamics of ultracold atoms: From Schrödinger to Dirac. — •Michael Merkl, Frank Zimmer, and Patrik Öhberg — Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom

In an atomic system a non-trivial gauge potential is induced with respect to the external motion of the atoms if two conditions are met. First, the considered atomic system should, during its time evolution, remain in space dependent eigenstates, so called dark-states. Secondly, if there are two degenerated dark-states, the resulting vector potential can be of a non-Abelian nature. These conditions can be fulfilled if one considers ultra-cold atoms with a tripod-type coupling scheme in the regime of electromagnetically induced transparency [1]. In the present talk we consider this tripod system in more detail. Hereby we distinguish the two limits of weak and strong non-Abelian dynamics. In the latter the dynamics of the atoms is described by an effective Dirac equation [2]. For both cases we consider the motion of the atoms with and without external trapping potentials and show that the corresponding wave-packet dynamics is highly non-trivial.

[1] J. Ruseckas, G. Juzeliūnas, P. Öhberg and M. Fleischhauer, Phys. Rev. Lett. 95, 010404 (2005)
[2] G. Juzeliūnas, J. Ruseckas, M. Lindberg, L. Santos and P. Öhberg, preprint

Q 63.6 Fr 15:15 3G/H

Fermi Gases with Arbitrary Spin — •Aristeu Lima[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

After the experimental realization of Bose-Einstein condensation in optical traps, where the spin degree of freedom of the bosonic atoms is no longer frozen, the question has arisen whether also fermionic atoms can be optically trapped. In fact, such a system has recently been experimentally realized with ^{173}Yb atoms [1]. Other promising examples of fermionic systems with a total angular moment F in the ground state which is larger than 1/2 are all alkali fermions (except ^{6}Li) and ^{53}Cr. Thus, now many interesting physical properties of spinor Fermi gases can be studied. Concerning the contact interaction, many pairing channels can occur. Furthermore, an additional dipole-dipole interaction, responsible for anisotropic superfluidity, plays a major role in ^{53}Cr, which has six valence electrons. Having these applications in mind, we calculate the ground-state energy of such systems perturbatively with respect to the two-particle interaction.

[1] T. Fukuhara et al. Phys. Rev. Lett. **98**, 030401 (2007)

Q 63.7 Fr 15:30 3G/H

Exact solution of strongly interacting quasi one-dimensional spinor bose gases — •Frank Deuretzbacher[1], Klaus Fredenhagen[2], Daniel Becker[1], Kai Bongs[3,4], Klaus Sengstock[3], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]II. Institut für Theoretische Physik, Universität Hamburg, Germany — [3]Institut für

Laserphysik, Universität Hamburg, Germany — [4]School of Physics and Astronomy, University of Birmingham, United Kingdom

One-dimensional systems of non-interacting fermions can be mapped to bosons with infinite δ-repulsion. This relationship has been found by Girardeau already in 1960 for spinless particles. We generalize Girardeau's mapping to bosons with spin. The surprising new result is that hard-core bosons with spin can be mapped to spinless non-interacting fermions *and* distinguishable spins.

Our mapping allows for exact calculations of spin densities and the energy spectrum. Another central result is that the momentum distribution depends on the symmetry of the spin wave function. States with completely symmetric spin wave functions have the typical momentum distribution of spinless bosons, whereas states with very antisymmetric spin wave functions have much broader and flatter momentum distributions which resemble the one of non-interacting fermions.

[1] F. Deuretzbacher, *et al.*, arXiv:0708.3039

Q 63.8 Fr 15:45 3G/H

Spontane Musterbildung in antiferromagnetischen Spinor-Bose-Einstein Kondensaten — •Jochen Kronjäger[1], Christoph Becker[1], Kai Bongs[2] und Klaus Sengstock[1] — [1]Institut für laser-Physik, Universität Hamburg — [2]Midlands Centre for Ultracold Atoms, University of Birmingham

Spontane Musterbildung ist ein verbreitetes Phänomen in räumlich ausgedehnten, nichtlinearen Medien. Die Musterbildung beruht oft auf der dynamischen Instabilität des homogenen Systems gegenüber räumlich oszillierenden Störungen, die exponentiell wachsen und schliesslich zu stabilen raum-zeitlichen Mustern sättigen.

Bose-Einstein Kondensate sind als nichtlineares Medium, in dem beispielsweise Solitonen auftreten, seit längerem bekannt. Auch neuere Arbeiten an Spinor-Kondensaten zielen auf räumliche Effekte ab. Nachgewiesen wurde z.B. bereits die spontane Bildung Spin-polarisierter Domänen in einem ferromagnetischen Spinor-Kondensat.

Unsere Messungen an elongierten $F = 2$ ^{87}Rb Spinor-Kondensaten zeigen erstmals die spontane Bildung von Domänen in einem *antiferromagnetisch* wechselwirkenden Spinor-System. Die Domänenbildung zeigt sich als regelmäßige Modulation des axialen Spins mit charakteristischer Wellenlänge. Induzierte Strukturbildung in einem gezielt angelegten Magnetfeld-Gradienten wird ebenfalls beobachtet, führt jedoch entgegen der Erwartung *nicht* zu regelmäßigen Mustern. Numerische und analytische Indizien unterstützen die Interpretation unserer Beobachtungen.